

Mini Risk Assessment
Plum fruit moth, *Cydia funebrana* (Treitschke)
[Lepidoptera: Tortricidae]

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Introduction

Cydia funebrana is an oligophagous pest, attacking the fruits of plum, cherry, peach, and other hosts typically within the plant family Rosaceae. This species is generally distributed in Europe, the Middle East, and northern Asia (CIE 1978). The likelihood and consequences of establishment by *C. funebrana* have been evaluated previously in a pathway-initiated risk assessment. *Cydia funebrana* was considered highly likely of becoming established in the US, if introduced; the consequences of its establishment for US agricultural and natural ecosystems were rated high (i.e., severe) (Cave and Lightfield 1997). This pest is also known as the red plum maggot and the plum fruit maggot (Zhang 1994).



Figure 1. Larva and adult of *Cydia funebrana*. Images not to scale.
[Larval image from Entopix; adult image from
<http://www.inra.fr/Internet/Produits/HYPPZ/IMAGES/7030280.jpg>.]

- 1. Ecological Suitability. Rating: High.** *Cydia funebrana* is found throughout most of the Palearctic, excluding the Near East and southeast Asia (USDA 1984). This climate within its range is generally characterized as dry or temperate (CAB 2003). The currently reported global distribution of *C. funebrana* suggests that the pest may be most closely associated with biomes that are generally classified as temperate broadleaf and mixed forests; temperate coniferous forests; or temperate grasslands, savannas, and shrublands. Based on the distribution of climate zones in the US, we estimate that approximately 79% of the continental US may be suitable for *C. funebrana* (Fig. 2). See Appendix A for a more complete description of this analysis.

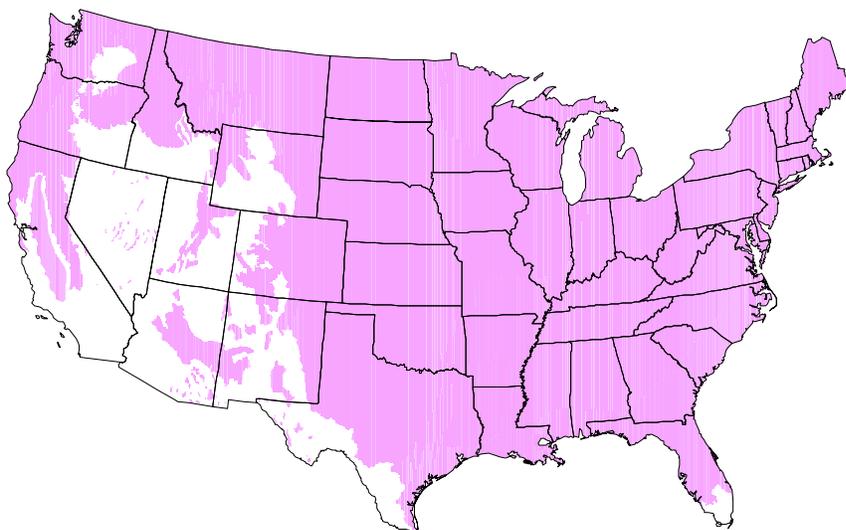


Figure 2. Predicted distribution of *Cydia funebrana* in the continental US.

- 2. Host Specificity/Availability. Rating Medium/Medium.** This pest feeds primarily on stone fruits (*Prunus* spp.), of which there are many species and cultivars in US fruit production areas; many potentially-suitable, wild hosts are also available in the US (USDA 2001). Primary hosts include apricot (*Prunus armeniaca*), cherry (*Prunus avium*), cherry or myrobalan plum/Asian almond (*Prunus cerasifera*), damson plum or wild bullace (*Prunus insititia*), Japanese cherry or Japanese plum (*Prunus japonica*), peach (*Prunus persica*), plum (*Prunus domestica*), sour cherry (*Prunus cerasus*), and wild blackthorn or sloe (*Prunus spinosa*) (USDA 1984, Zhang 1994, Yang-Seop and Kyu-Tek 1997, CAB 2003).

Secondary hosts include apple (*Malus domestica*, *M. sylvestris*), bitter almond (*Prunus dulcis*), English walnut (*Juglans regia*), European chestnut (*Castanea sativa*), and pear (*Pyrus communis*) (Popova 1971, USDA 1984, Yang-Seop and Kyu-Tek 1997, CAB 2003).

See Appendix B for maps describing where various hosts are grown commercially in the US.

- 3. Survey Methodology. Rating: Medium.** Eggs, larvae, and pupae of *C. funebrana* may be detected by visual inspection (USDA 1984). Fruit stalks, fruit, and leaves should be examined for eggs; for larvae, fruit should be inspected for entry holes or frass; fruit should be dissected to find larvae in the flesh of the fruit near the seed; bark, branches, and root collars should be examined for pupae (Vernon 1971, USDA 1984, Pluciennik et al. 1999).

Robinson mercury-vapor light traps have been used to monitor flight activity of adults (Vernon 1971), but these traps indiscriminately attract many insects.

Synthetic sex pheromones may also be used to monitor for adults. The *Z*- and *E*-isomers of 8-dodecenyl acetate are components of the sex pheromone for *C. funebrana* (Odinokov et al. 1985). These compounds in a ratio between 96:4 and 98:2 [*Z*:*E*] are most attractive to males (reviewed in Audemard 1992). Such a pheromone blend has been commercialized in the product Funemone to monitor populations of the pest (Bhardwaj 1987). Pheromone may be dispensed using impregnated rubber septa or polyethylene microcapillary tubes (reviewed in Audemard 1992). The lure has been used with Traptest traps, delta traps (Molinari 1995), and Pherocon 1C traps (Alford 1978). In the Czech Republic, a mixture of five compounds [(*Z*)-8-dodecenyl acetate, (*E*)-8-dodecenyl acetate, (*Z*)-8-tetradecenyl acetate, (*Z*)-10-tetradecenyl acetate, and tetradecyl acetate] was used in delta traps to monitor for the moth (Kocourek et al. 1995). Kocourek et al. (1995) placed 1-2 traps, 160 cm above the soil, in each commercial stone fruit orchard. Delta traps were replaced twice a week and lures were replaced every 6 weeks (Kocourek et al. 1995). Pheromone traps have been used effectively to monitor adult flight activity and make treatment recommendations (Iacob 1977a, b). Apostolov and Vurbanova (1980) recommend placing traps on the edge of orchards, rather than in the center, to improve detection efficiency. Lures for *C. funebrana* may be used in the same trap with lures for *Cydia pomonella* or *Lymantria dispar* (Schwalbe and Mastro 1988).

However, Funemone may also attract other Lepidoptera including: *Acleris variegana*, *Agrotis excelamationis*, *Anthophila fabricana*, *Argyresthia pruniella*, *Caradrina morpheus*, *Celypha rosaceana*, *Celypha striana*, *Cnephasia* spp., *Cydia* spp. (including false codling moth), *Enarmonia formosana*, *Epiblema* spp., *Esperia sulphurella*, *Glyphipterix simpliciella*, *Laspeyresia aurana*, *Nola cucullatella*, *Oligia* spp., *Pandemis heparana*, *Pammene* spp., *Xanthorhoe ferrugata*, *Xestia sexstrigata*, and others (Garrido and Jimenez 1975, Alford 1978, Sziráki 1978, Hrdý et al. 1979, Hrdy et al. 1989, Hrdy et al. 1993). Many of these taxa are difficult to distinguish from *C. funebrana* based on external morphology (Appendix C, Hrdy et al. 1996). Consequently, moth identity should be confirmed by a trained taxonomist.

Sex pheromones have been used for mating disruption of *C. funebrana*. In Switzerland, Germany, and Romania, two component blends were used with mixed success (reviewed in Audemard 1992). In Ukraine, the compounds (*Z*)-8-dodecenol acetate, (*E*)-8-dodecenol acetate, and dodecanol acetate are used in a ratio of 96:4:1000 to disrupt mating of *C. funebrana* (Tertyshny 1997).

The compound (*Z*)-6-dodecenyl acetate reduces the attractiveness of pheromone lures to male *C. funebrana*; the presence of this compound makes traps more selective for *Grapholita molesta* (Tóth et al. 1991).

In Italy, temperature driven models are used to describe and predict the phenology of *C. funebrana*; such a model has proven useful to make informed pest-management decisions and to structure field surveys (Bugiani et al. 2000). A similar model was developed to predict peak male flight activity (Kocourek et al. 1995).

- 4. Taxonomic Recognition. Rating: Medium.** *Cydia funebrana* may be easily confused with another Tortricid pest, *C. molesta*, that is widely distributed in North America. The two species share several plant hosts including apricot, nectarine, peach (*Prunus* spp.), and secondary hosts including apple and pear (*Malus* and *Pyrus* spp., respectively) (CAB 2003). Adults may be identified reliably by distinct differences in genitalia (CAB 2003) and close examination of morphological characters (USDA 1984).

See Appendix C for a more complete morphological and taxonomic description of *C. funebrana*.

- 5. Entry Potential. Rating: High.** Interceptions of “*Cydia* sp.” have been reported nearly 6,700 times since 1985; however, no specimens were identified specifically as *C. funebrana* (USDA 2003). Annually, about 350 (± 33 standard error of the mean) interceptions of “*Cydia* sp.” have been reported (USDA 2003). Interceptions have been associated predominantly with cargo (87%) and international airline passengers (12%). Although the pest has been intercepted at 52 ports of entry in the United States, the majority of interceptions have been reported from Los Angeles (39%), Honolulu (22%), JFK International Airport (6%), Boston (6%), San Francisco (4%), Seattle (4%), Des Plaines (4%), and Chicago (3%). These ports are the first points of entry for cargo or airline passengers coming into the US and do not necessarily represent the intended final destination of infested material. Movement of potentially infested material is more fully characterized in the next section of this document.
- 6. Destination of Infested Material. Rating: High.** When an actionable pest is intercepted, officers ask for the intended final destination of the conveyance. Infested cargo or airline passengers were destined for 44 states, including the District of Columbia. The most commonly reported destinations were California (46%), Hawaii (20%), Illinois (6%), Massachusetts (6%), New York (5%), and Washington (state) (3%). We note that some portion of each of the states in the continental US has a climate and hosts that would be suitable for establishment by *C. funebrana*.
- 7. Potential Economic Impact. Rating: Medium.** *Cydia funebrana* is noted as a pest of economic importance throughout Europe (Bradley et al. 1979a, Alford 1981, Hrdy et al. 1993, Kocourek et al. 1995, Pluciennik et al. 1999), Eurasia (Guerin et al. 1986), the former Soviet Union (Popova 1971, Vernon 1971, USDA 1984), India (Bhardwaj 1987) and the Far East (Popova 1971). Integrated fruit protection plans were created in Europe and Mediterranean regions because of the

pest (Audemard 1992). Yield losses ranging from 25 – 100% have been documented in Austria, Belarus, Bulgaria, Crimea, Georgia, Germany, Moldavia, Switzerland, Ukraine and Yugoslavia (Popova 1971, Stamenkovic et al. 1984, USDA 1984, Arnaoudov and Andreev 2002).

Upon hatching, larvae bore into fruit and feed progressively from the flesh region to the pit region of *Prunus* spp. (Sharma 1987). Though the entrance hole itself may be inconspicuous, feeding damage causes fruit discoloration, gummosis (gummy exudates visible on fruit exterior), premature ripening and fruit drop (Pluciennik et al. 1999, Rauleder et al. 2002, CAB 2003), which ultimately cause reduced marketability and economic losses. The second generation is considered the most damaging, and can cause significant yield reductions (Kocourek et al. 1995). Early ripening cultivars or those with tender skin may incur greater damage (Vernon 1971, Pluciennik et al. 1999). Reduced availability of marketable fruit earlier in the season when premium prices can be sought may also contribute to economic losses (Batinica and Muratovic 1972).

- 8. Establishment Potential. Rating: High.** No occurrences of *C. funebrana* have been reported in the wild. However, this pest is likely to survive the climatic conditions in much of the continental US (Fig. 2). Plants belonging to the genus *Prunus* (and more generally to the family Rosaceae) are also relatively common. Thus, conditions are favorable for establishment of this pest. This conclusion corroborates the results of other risk assessments for this pest (Cave and Lightfield 1997).

See Appendix D for a more complete description of the biology of *C. funebrana*.

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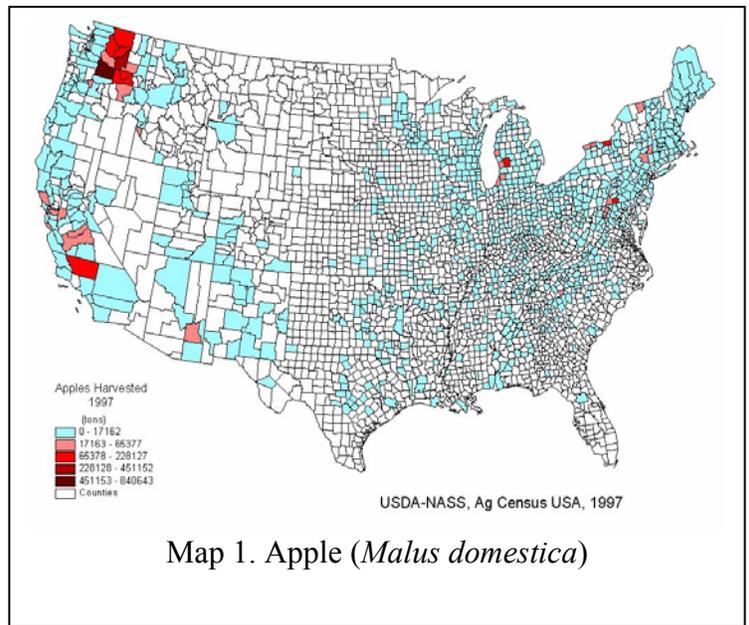
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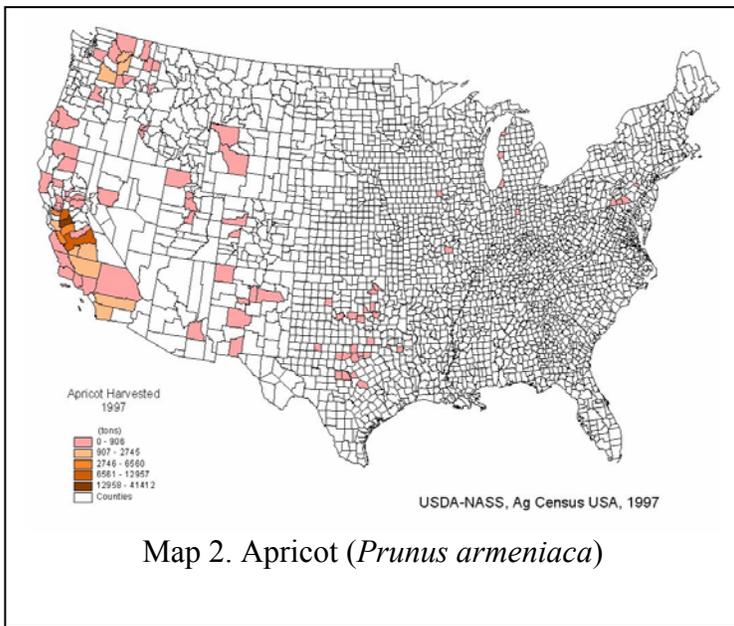
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Appendix A. Comparison of climate zones. To determine the potential distribution of a quarantine pest in the US, we first collected information about the worldwide geographic distribution of the species (CAB 2003). We then identified which biomes (i.e., habitat types), as defined by the World Wildlife Fund (Olson et al. 2001), occurred within each country or municipality reported for the distribution of the species. Biomes were identified using a geographic information system (e.g., ArcView 3.2). An Excel spreadsheet summarizing the occurrence of biomes in each nation or municipality was prepared. The list was sorted based on the total number of biomes that occurred in each country/municipality. The list was then analyzed to determine the minimum number of biomes that could account for the reported worldwide distribution of the species. Biomes that occurred in countries/municipalities with only one biome were first selected. We then examined each country/municipality with multiple biomes to determine if at least one of its biomes had been selected. If not, an additional biome was selected that occurred in the greatest number of countries or municipalities that had not yet been accounted for. In the event of a tie, the biome that was reported more frequently from the entire species' distribution was selected. The process of selecting additional biomes continued until at least one biome was selected for each country. The set of selected biomes was compared to the occurrence of those biomes in the US.

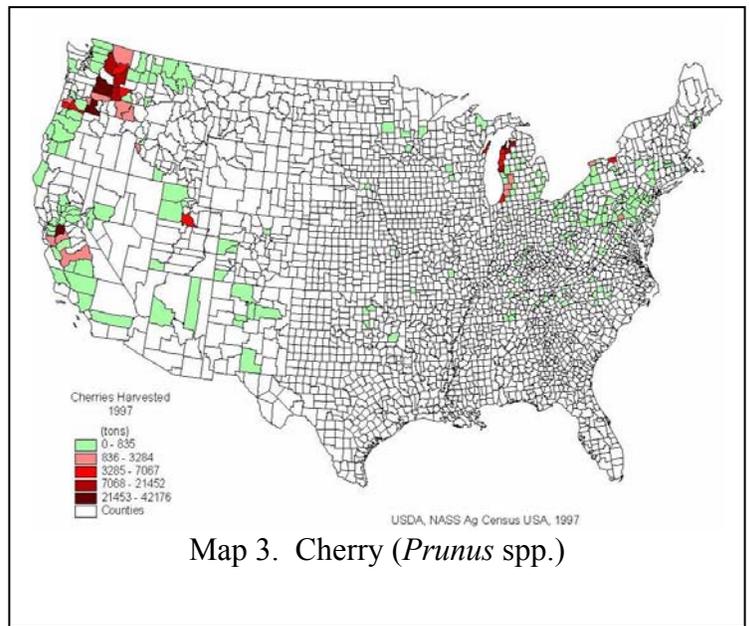
Appendix B. Commercial production of hosts of *Cydia funebrana* in the continental US.



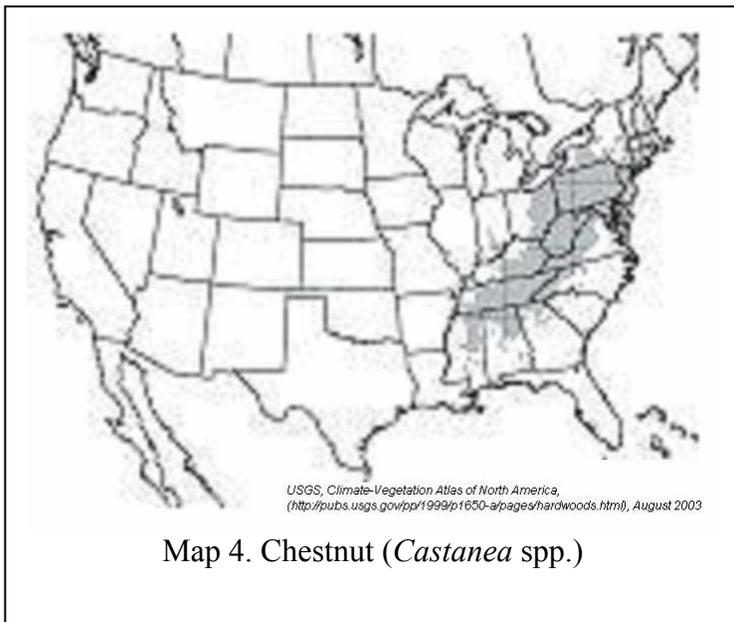
Map 1. Apple (*Malus domestica*)



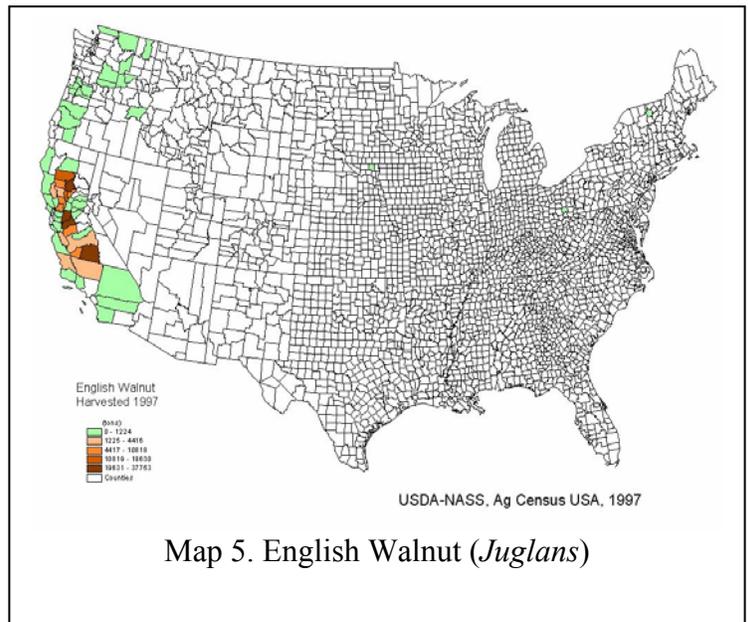
Map 2. Apricot (*Prunus armeniaca*)



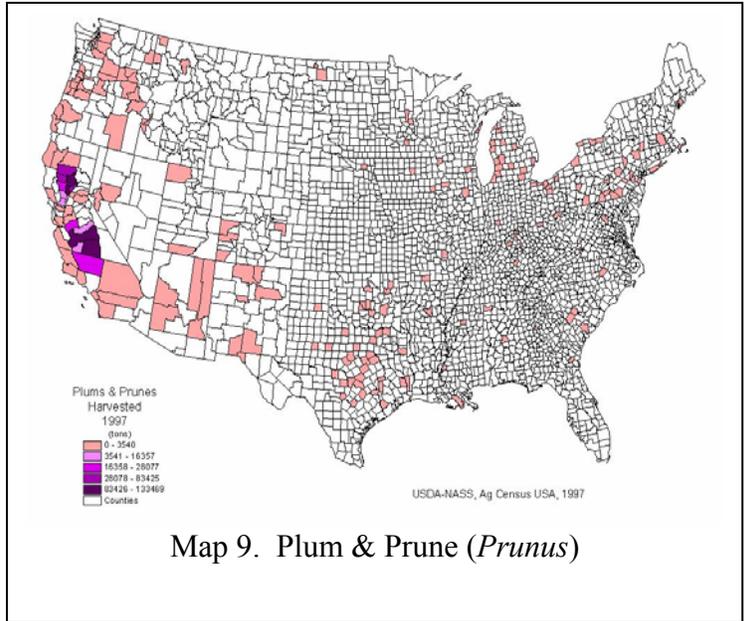
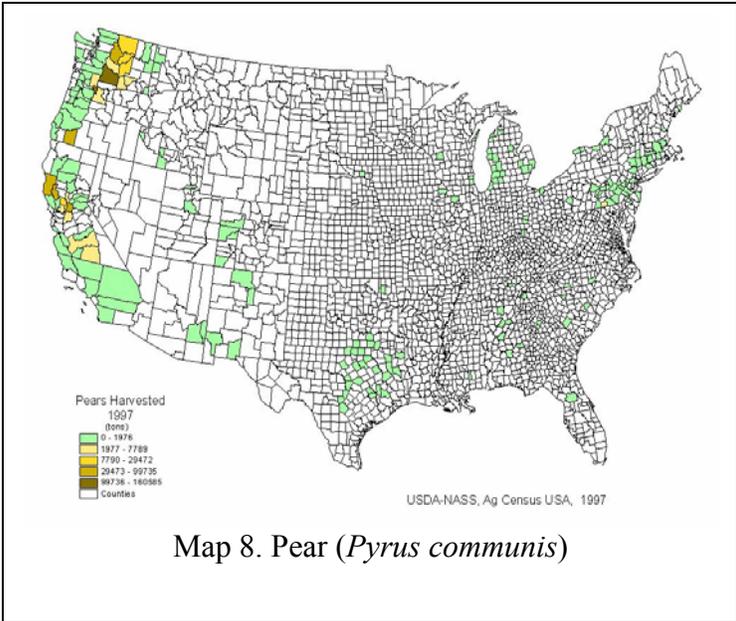
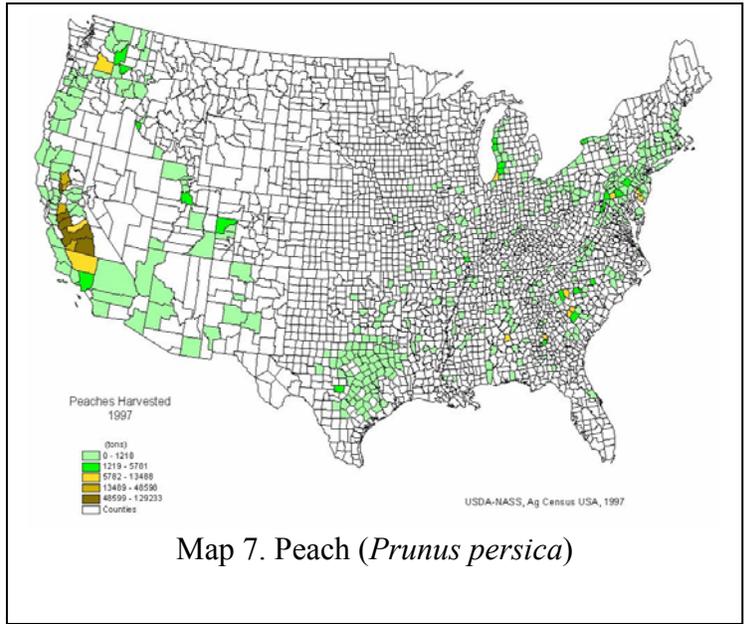
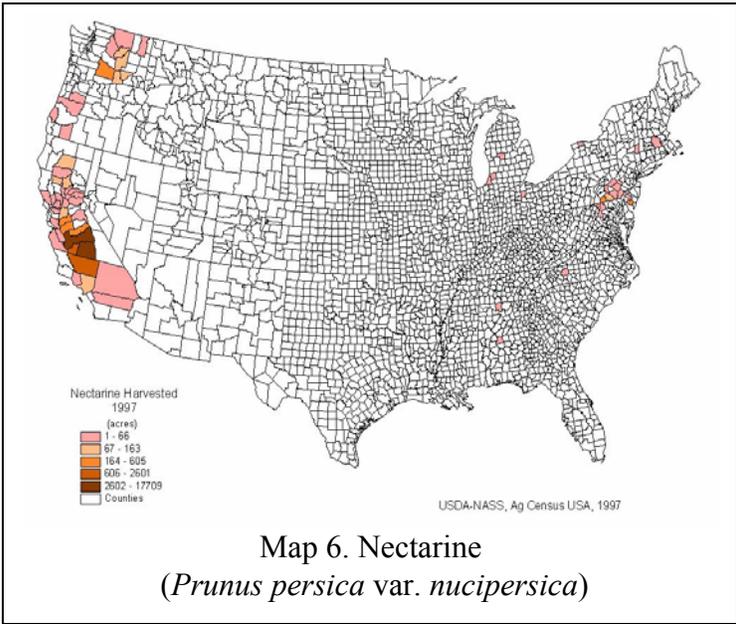
Map 3. Cherry (*Prunus* spp.)



Map 4. Chestnut (*Castanea* spp.)



Map 5. English Walnut (*Juglans*)



Appendix C. Taxonomy of *Cydia funebrana* (Treitschke) and related Tortricidae (prepared by M. DaCosta)



Male

Female

Figure C1. *Cydia funebrana*-dorsal view male and female 10-15 mm
[Reproduced from Bradley et al (1979b)]

Synonyms

There are several synonyms of the genus *Cydia*, and two of these deserve special mention because of their especially tangled relationship with *Cydia*. The first synonym is *Endopisa* which was described by Guenée in 1845. Subsequently, in the 1860s, Clemens described a number of species and placed them in the genus *Endopiza*-a misspelling of *Endopisa*. Clemens' specimens do not belong in *Cydia* and were placed in the "genus" *Endopiza*. Obratsov (1953) proposed the genus *Paralobesia* as a replacement for *Endopiza* to correct for the poor use of nomenclature. Thus, while *Endopisa* is a synonym of *Cydia*, *Endopiza* is "conceptually" a synonym of *Paralobesia* (John Brown, Smithsonian Institution, Washington, DC, personal communication).

The second synonym, *Grapholita* has been treated as the closest relative of *Cydia* (Heinrich 1926, Obratsov 1959), a subgenus of *Cydia* (Bradley 1972, Leraut 1980, Vives Moreno 1994, cited in Komai 1999), and as a junior synonym of *Cydia* by Larsen and Vihelmsen (1990, cited in Komai 1999). Razowski (1992) also treated *Grapholita* as synonym of *Cydia* based on characters of the scent organs and female genitalia, though previously he had considered them separate genera (Razowski 1989, cited in Komai 1999). Brown (1979) treated the two as separate genera. Razowski (1996) confirmed the only autapomorphy of *Cydia* was presence of diversticulum on dorso-posterior part of the corpus bursa. According to Bae and Park (1997), *Grapholita* can be separated from related genera by (1) the degree of development of coremata, (2) shape of cingulum (either "angular plate or short conical structure") of ductus bursa. Komai (1999) constructed a phylogeny of the tribe and treated the two as separate genera with *funebrana* as a species in the genus *Grapholita* subgenus *Aspila* (Fig. C2). Currently, *Cydia* and *Grapholita* are considered separate genera (John Brown, Smithsonian Institution, Washington, DC, personal communication).

Cydia has been described as a "dustbin" genus with a large number of species not necessarily related to each other (Robinson et al. 1994). A treatment defining species

limits would be helpful in eliminating some of the confusion exemplified by *Endopisa*, *Endopiza* and *Grapholita*.

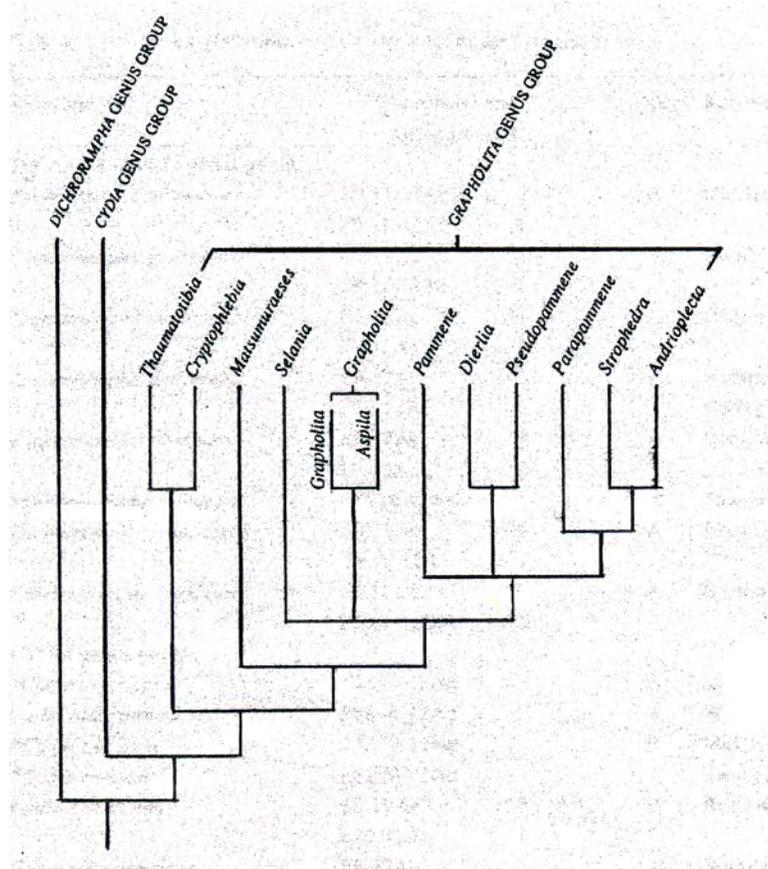


Figure C2. Phylogeny of the tribe Grapholitini in the Palearctic region
[Reproduced from Komai (1999)]

Synonymy at the generic level: (John Brown, Smithsonian Institution, Washington, DC, personal communication)

Cydia Hübner, [1825] 1816, Verz. Bekannter Schmett.: 375. Type species: *Phalaena pomonella* Linnaeus, 1758.

- *Laspeyresia* Hübner, [1825] 1816, Verz. Bekannter Schmett.: 381. Type species: *Tortrix corollana* Hübner [1823]. [preoccupied]
- *Erminea* Kirby & Spence, 1826, Introd. Entomol. 3: 122. Type species: *Phalaena pomonella* Linnaeus, 1758.
- *Carpocapsa* Treitschke, 1829, in Ochseneheimer, Schmett. Eur. 7: 231. Type species: *Phalaena pomonella* Linnaeus, 1758.
- *Coccys* Treitschke, 1829, in Ochseneheimer, Schmett. Eur. 7:230. Type species: *Tortrix strobilana* Hübner, [1799].
- *Semasia* Stephens, 1829, Cat. Brit. Insects: 47. Type species: *Phalaena pomonella* Linnaeus, 1758.

- *Carpocampa* Harris, 1841, Rept. Insects Mass. Injurious Veget.: 351. [emendation of *Carpocapsa*]
- *Endopisa* Guenée, 1845, Ann. Soc. Entomol. Fr. (2) 3: 182. Type species: *Grapholitha nebritana* Treitschke, 1830.
- *Cerata* Stephens, 1852, List Spec. Brit. Anim. Colln. Brit. Mus. 10: 77. Type species: *Penthina servillana* Duponchel, 1836.
- *Endopiza* Guenée, 1860, Proc. Acad. Nat. Sci. Philadelphia 1860: 359. [misspelling of *Endopisa*]
- *Melissopus* Riley, 1882, Trans. Acad. Sci. St. Louis 4: 322. Type species: *Carpocapsa latiferreana* Walsingham, 1879.
- *Melisopus* Riley, 1881, Trans. Acad. Sci. St. Louis 4: 322. [misspelling of *Melissopus*]
- *Mellisopus* Fernald, 1882, Trans. Amer. Entomol. Soc. 10: 54. [misspelling of *Melissopis*]
- *Melliopus* Packard, 1890, Journal: 00. [misspelling of *Melissopis*]
- *Adenoneura* Walsingham, 1907, in Sharp, Fauna Hawaiiensis or the Zool. Of the Sandwich (Hawaiian) Isles 1(5): 677. Type species: *Adenoneura falsifalcellum* Walsingham, 1907.
- *Mellisopus* Fernald, 1908, Genera Tortricidae Types: 60. [misspelling of *Melissopis*]
- *Crobylophora* Kennel, 1908, Zool. Stuttg. 54 (1): 294. Type species: *Tortrix inquinatana* Hübner, [1779]. [preoccupied]
- *Hedulia* Heinrich, 1926, Bull. U.S. Natl. Mus. 132: 65. Type species: *Hedulia injectiva* Heinrich, 1926.
- *Lasperesia* Wu, 1938, Cat. Insect. Sinensium 4: 57. [misspelling of *Laspeyresia*]
- *Kenneliola* Paclt, 1951, Revue Fr. Lepid. 13: 127. [replacement name for *Crobylophora*]
- *Lespeyresia* Gozmány, 1957, Acta Zool. Acad. Sci. Hung. 3: 134. [misspelling of *Laspeyresia*]
- *Pseudotomoides* Obraztsov, 1959, Tijdschr. Entomol. 102: 200. Type species: *Phalaena strobilella* Linnaeus, 1758.
- *Crobylophora* Obraztsov, 1959, Tijdschr. Entomol. 102: 176. [misspelling of *Crobylophora*]
- *Erminia* Obraztsov, 1959, Tijdschr. Entomol. 102: 175. [misspelling of *Erminea*]
- *Phanetoprepa* Obraztsov, 1968, J. New York Entomol. Soc. 76: 236. Type species: *Phanetoprepa agenjoi* Obraztsov, 1968.
- *Danilevskia* Kuznetsov, 1970, Entomol. Obozr. 49: 446. Type species: *Danilevskia silvana* Kuznetsov, 1970.
- *Dicraniana* Diakonoff, 1984, Entomol. Gall. 1: 162. Type species: *Semasia seriana* Kennel, 1901. [subgenus of *Cydia*]

At the species level:

funebrana Treitschke, 1835

- None

Description [Description from Bradley et al. (1979a)]

Head: Labial palpus and frons grayish dark brown/black.

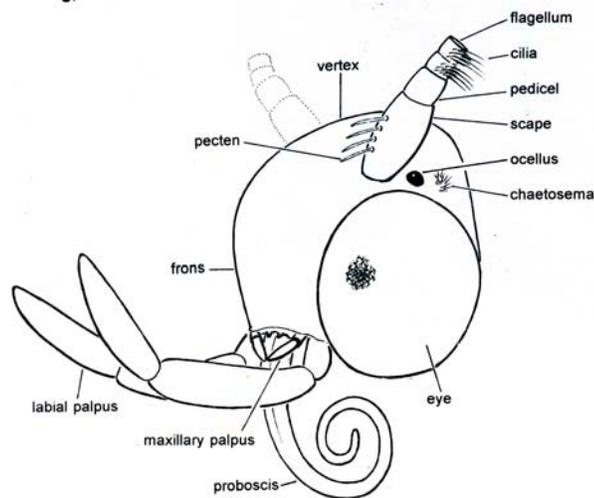


Figure C3. Ventro-lateral view of general moth head with appendages
[Reproduced from Robinson et al. (1994)]

Wings: As in Figure C1, Figure C4 shows variation that may be encountered in tortricoid wing patterns. Forewing ground color white, overlaid with dark brown/black except obscure pairs of interspaces between poorly defined blackish brown short or fine transverse lines or marks (strigulae) on costa; fasciate markings blackish brown, indeterminate except outer edge of sub-basal fascia which is weakly indicated dorsally, a minute indistinct, white discocellular spot present; distal area irrorate (tips of scales) with white or grayish white, most pronounced in ocellus; a similar irroration medio-dorsally, forming an indistinct blotch; ocellus comprising usually four black dots, edged laterally by a thick bluish-gray fine transverse line (stria) on inner margin and a similar but thinner stria on outer margin; cilia of uniform color with wing basally, otherwise gray, with a black sub-basal line indented sub-apically. Hindwing dark brown/black, lighter basally and along termen; cilia grayish white, with a dark brown/black sub-basal line.

Variation: Individual variation occurs in the clarity of the white interspaces on the costa and in the strength of the whitish irroration in the distal and medio-dorsal areas of the fore-wing.

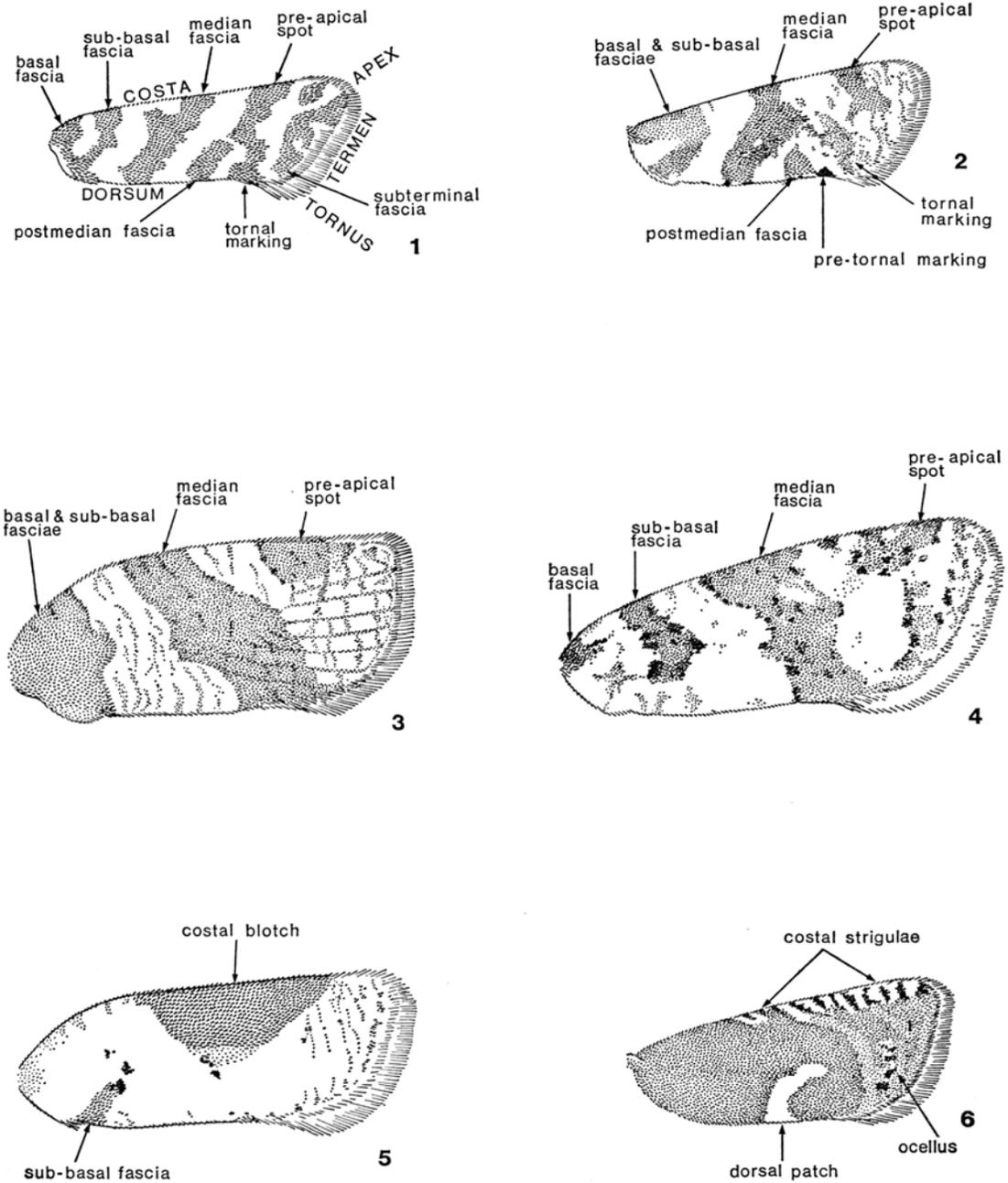


Figure C4. Variation in wing patterns of Tortricoid moths
[Reproduced from Bradley et al. (1979b)]

Ovum: Resembling a lentil in shape; translucent white, gradually becoming yellow.

Larva: Head dark brown to black; prothorax pale yellow, prothoracic plate pale brown with darker brown mottling along posterior margin; thoracic legs pale yellow; abdomen translucent white, becoming pink dorsally and yellowish ventrally as the larva matures; small, flat or slightly elevated chitinized area with between 1 and 4 setae (pinacula) light brown, inconspicuous; sclerotized plate about spiracles (peritreme) brown, inconspicuous; anal plate pale brown, marked with small blackish spots; anal comb with 4-7 prongs and 1-3 additional prongs laterally. Head is dark brown to black in all instars but becomes lighter brown before pupation, and the body is translucent white up to the last instar and then gradually becomes pink, the small spine (spinules) appearing as bright spots of pink in the fully fed larva, while the prothoracic and anal plates are blackish gray in early instars with darker markings; these and other sclerotized parts, such as pinacula, spiracles and spinules, become progressively less heavily pigmented as the larva matures.

Pupa: Light brown. April and May; in a cocoon spun up in almost any convenient situation such as dead wood, a crevice in the bark of a tree, under moss or in the soil. Cocoons frequently found in wicker baskets or containers used for carrying fruit.

Genitalia:

Structures labeled with lettered arrows here were not labeled in Bradley et al. (1979a). Arrows were labeled to assist differentiation of *C. funebrana* (Treitschke) from *C. molesta* (Busck). Sketches of *C. tenebrosana* (Duponchel) were not available. Terminology follows Klots (1970).

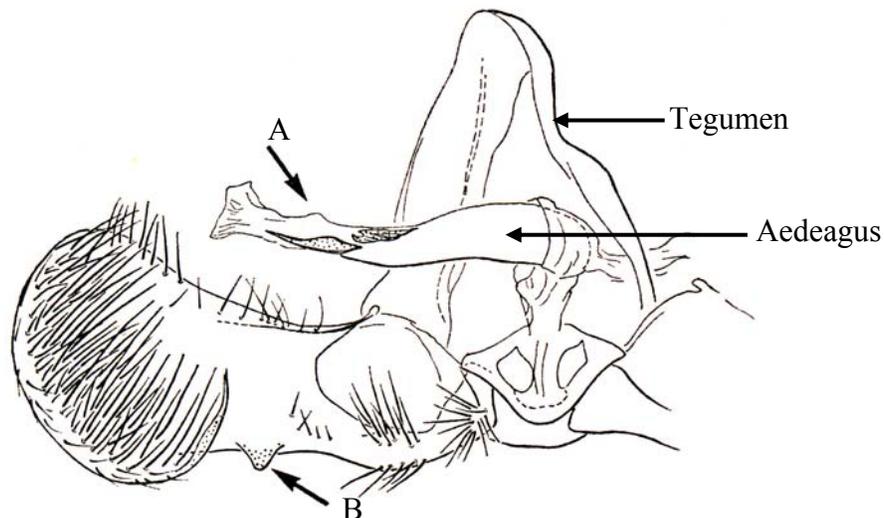


Figure C5. *Cydia funebrana*-ventral view male genitalia. A-vesica and/or cornutii, B-structure projecting beyond margin of valve [Reproduced from Bradley et al. (1979b)].

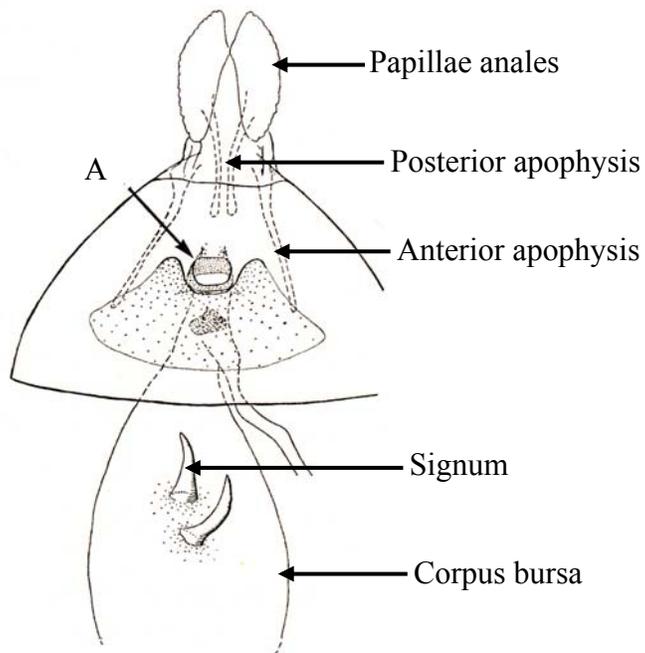


Figure C6. *Cydia funebrana*-ventral view female genitalia. A-ostium bursa and surrounding structures [Reproduced from Bradley et al. (1979b)].

Similar species:

Cydia funebrana is similar in appearance to *Cydia molesta* and *Cydia tenebrosana*.

Cydia molesta is distinguished from *C. funebrana* by its generally smaller size, the better defined fasciate markings and white discocellular spot of the forewing, and in the male also by the patch of pale scales along the middle of the termen of the hindwing (Fig C7).

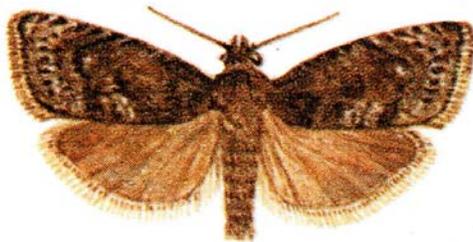


Figure C7. *Cydia molesta* (Busck)- dorsal view male [Reproduced from Bradley et al. (1979b)]

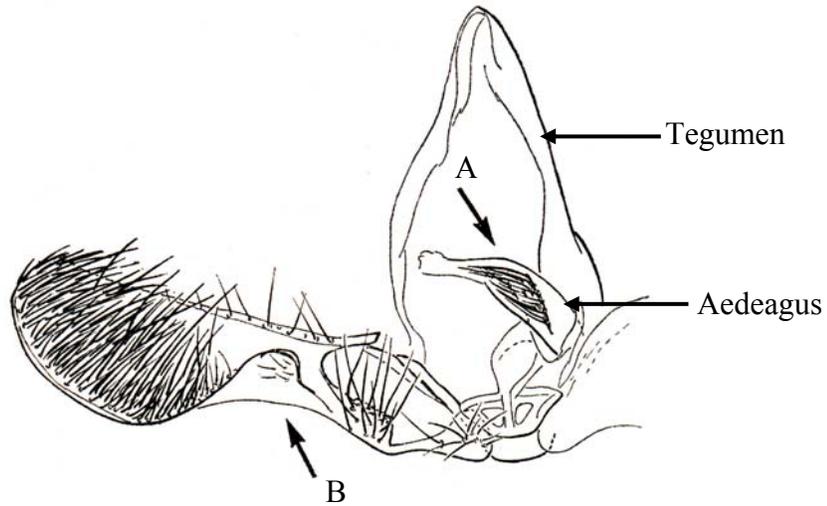


Figure C8. *Cydia molesta* (Busck)-ventral view male genital capsule. A-vesica and/or cornuti, B-structure projecting either away from inner margin of valve [Reproduced from Bradley et al. (1979b)]

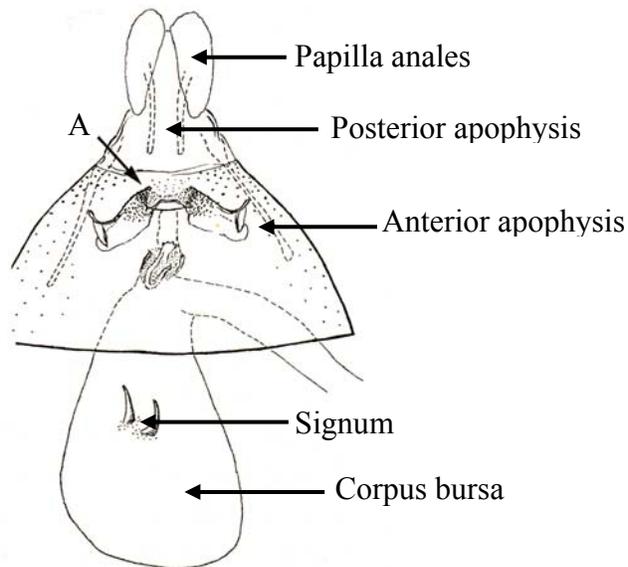


Figure C9. *Cydia molesta* (Busck)-ventral view female genitalia. A-ostium bursa and surrounding structures [Reproduced from Bradley et al. (1979b)]

Cydia tenebrosana is distinguished from *C. funebrana* by the grayish white labial palpi and frons and the comparatively uniform purplish dark brown/black general coloration of the forewing (Fig C10).

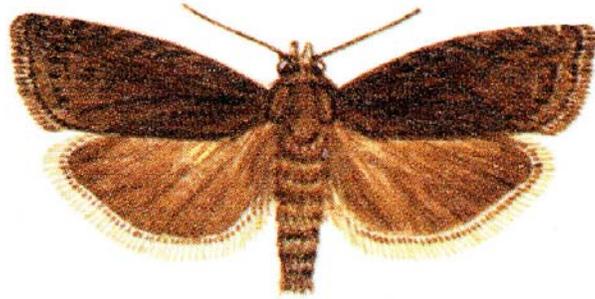


Figure C10. *Cydia tenebrosana* (Duponchel)- Dorsal view male [Reproduced from Bradley et al. (1979b)].

Appendix D. Biology of *Cydia funebrana*

Population phenology

Cydia funebrana has 1-3 generations annually (Molinari 1995, Molinari et al. 1997, Butturini et al. 2000). The number of generations varies from northern to southern latitudes. Generally, one generation occurs in England (Vernon 1971), Poland (Kozłowski 1994, Pluciennik et al. 1999), and the Ukraine (Pluciennik et al. 1999). Two generations occur throughout most of the former Czechoslovakia, though a partial third generation may occur in southern areas during very warm seasons (Hrdy et al. 1996). In Yugoslavia, 2-3 generations develop, depending on plum variety (Batinica and Muratovic 1972). Three generations occur in Hungary and the Caucus region of the former Soviet Union (Sáring and Deseo 1972).

The number of generations and the size of the population in each generation is determined by several factors including photoperiod, temperature, humidity, latitude, longitude, altitude, food quality, predators, and parasitoids (Batinica and Muratovic 1972, Sáring and Deseo 1972, Charmillot et al. 1979, Hrdy et al. 1996, Rauleder et al. 2002). *Cydia funebrana* thrives in climates that are conducive to the production of stone fruits, i.e., warm January and February temperatures (mean 5.8-5.9°C), high precipitation (up to 153.4 cm/year) and high relative humidity (70-78%) (Popova 1971). In southern Europe, the size of the third population increases at lower altitudes (Hrdy et al. 1996). In the former Czechoslovakia the second generation is smaller in the sub-highland regions during colder years (Hrdy et al. 1996). In northern Italy, pheromone trap catches reach a maximum later in the season (Molinari 1995).

Populations of *C. funebrana* are typically active from spring through mid- to late-summer. In England, peak emergence occurs between late May and mid-June, depending on spring temperatures (Vernon 1971). In Poland, first emergence occurs in May, and emergence of the summer generation takes place between late June and late July (Kozłowski 1994). In northern Italy, maximum flight activity peaks occur in early-mid May, late June to early July, and early August (Viggiani 1975, Molinari 1995).

Distinguishing between generations can be difficult because emergence dates (i.e., eclosion of adults from pupae) overlap. In Germany where summers are generally cooler, overlapping emergence is not observed (Sáring and Deseo 1972).

Stage specific biology

Adult emergence is difficult to predict from cumulative degree days or from the phenological development of stone fruits (Popova 1971, Sáring and Deseo 1972). Most moths emerge within 10 days of the first moth emergence (Popova, 1971). The seasonal flight period of *C. funebrana* lasts an average of 175 days (Stamenkovic et al. 1984). Flight duration per generation lasts two or more months (Sáring and Deseo

1972). In colder regions, the flight period ends earlier (after accumulation of significantly fewer degree days) compared to warmer regions (Hrdy et al. 1996).

Moth activity is greatest between 18 and 22°C (Popova 1971, Sáringer and Deseo 1972). Moths are primarily active at night, and rest during the day high in the tree canopy (USDA 1984). Mating occurs in the early morning, 2 hours before sunrise (Charmillot et al. 1979). Each male mates 3.7 ± 0.5 times on average, and up to 10 times (Velcheva 1981).

Eggs are laid between 3 and 10 days after emergence, primarily during afternoon and evening hours, though some egg laying occurs in the morning (Charmillot et al. 1979, Kozłowski 1994). The optimal temperature range for oviposition is between 24 and 26°C (Popova 1971). Egg-laying is adversely affected by low relative humidity and high temperatures (Arnaoudov and Andreev 2002). Between 1 and 9 eggs are laid in full sun on the fruit surface (Vernon 1971) or on leaves and stems near the fruit (USDA 1984). Eggs are usually laid singly or in small groups (USDA 1984). Under poor crop conditions or limited host availability, female moths oviposit in groups of 3-5 eggs, to a maximum of 10-16 eggs. When host plants are severely limited (near total crop failure), groups of 18-33 eggs have been observed on very few fruit (Popova 1971). Adults of the overwintering generation generally lay eggs in early-mid May, and, depending on temperatures, egg-laying may be delayed up to 2 months (Sáringer and Deseo 1972). Later generations lay eggs between mid-June and August (Vernon 1971).

Average fecundity is affected by photoperiod and duration of the egg and first instar of the mother (Deseo and Sáringer 1975). Greater fecundity (68-139 eggs) is often observed under laboratory conditions than under natural conditions (10-60 eggs) (Popova 1971). Fecundity may vary geographically. For example, in Bulgaria, average fecundity is 15-25 eggs; in Yugoslavia, 35 eggs; and in Switzerland, 44 eggs (Popova 1971). Fecundity may also vary between generations. For example, in Romania first generation females can lay between 20-85 eggs, while second generation females lay between 100-200 eggs (USDA 1984).

Female moths live an average of 11-13 days under laboratory conditions (Popova 1971, Rauleder et al. 2002). Male moths have a shorter life span and live an average of 8 days (Rauleder et al. 2002).

Egg development has three stages: “milky”, “red ring”, and “black head” (Rauleder et al. 2002). The black-head stage represents development of first generation larvae and typically occurs in mid- to late July (Witkowska et al. 1969, Witkowska and Wojnarowska 1970). In Poland, the black-head stage occurs 10 to 20 days after adult emergence (Kozłowski 1994). Eggs develop in 5-9 days, and most eggs hatch in less than 7 days (Domanskii 1972, Molinari 1995).

Larvae bore into fruit within 0.5-2 hours after egg-hatch (Popova 1971, Domanskii 1972). Before feeding begins, the entrance hole is sealed with deposits of chewed fruit skin bound with silk (Popova 1971). Larvae can move from one fruit to another

(Popova 1971). Larvae complete development in 3 instars; in total, larval stages were observed to last 15-17 days (Popova 1971), although the duration could be longer or shorter depending on temperatures. Intense competition exists between established larvae; consequently, cannibalism can occur (Vernon 1971).

Mature larvae leave the fruit to pupate under bark crevices, at the root collar, under leaf litter, or in soil (Popova 1971). Larvae may hibernate in sheltered sites such as old trees or near buildings and can complete development faster than larvae in orchards (Polesny et al. 2000). Even when larvae attempt to protect themselves from winter weather, most (67.9%) may not survive the season (Popova 1971).

Larval density varies within a generation depending on the variety of the host plant (e.g., plum, Batinica and Muratovic 1972). Rates of infestation vary significantly between plum cultivars but the frequency of infestation is not correlated with the timing of fruit harvest or to the fruit yield (Pluciennik et al. 1999).

Pupae enter diapause at a critical photoperiod of 14-15 hours in Hungary (Sáringer and Deseo 1972). Diapause is determined primarily by photoperiod, followed by temperature, and lastly, host ripening. Pupation occurs between late April-August, and the duration can vary depending on weather (Sáringer and Deseo 1972). “*Cydia funebrana* overwinter as pupae. Temperature strongly affects diapausing pupae (Arnaoudov and Andreev 2002). In areas where only 2 generations occur, the pupal stage persists for 35-55 day, whereas when 3 generations occur, pupal development is complete in 6-16 days (Popova 1971)

Several studies describe the developmental thresholds and accumulated degree days necessary for the completion of each life stage (Table D1).

Table D1. Developmental threshold and degree day requirements for *C. funebrana*

Stage	Developmental threshold (°C)	Degree Days	Notes	Reference
Egg	10	75	Laboratory study	(Charmillot et al. 1979)
	11	Not specified	Laboratory study	(Butturini et al. 2000)
Larva	10	Not specified	Laboratory study	(Butturini et al. 2000)
	10	175	Laboratory study	(Charmillot et al. 1979)
Pupa	10	160	Laboratory study	(Charmillot et al. 1979)
	10.8	Not specified	Laboratory study	(Butturini et al. 2000)
Adult	Not specified	280	96% emergence overwintering generation	(Kocourek et al. 1995)
	Not specified	380-420	5-10% emergence summer generation	(Kocourek et al. 1995)
	5.8	Not specified	Laboratory studies; females	(Butturini et al. 2000)
	10	30	First male moths caught in pheromone traps in Switzerland	(Charmillot et al. 1979)

Stage	Developmental threshold (°C)	Degree Days	Notes	Reference
	10	400-500	Second generation flight begins in Switzerland	(Charmillot et al. 1979)
	10 (“biological zero point” under lab conditions)	475-540	Flight of summer generation 1 in Hungary with 4 yr. avg. flight duration of 51 days	(Sáringér and Deseo 1972)
	10 (“biological zero point” under lab conditions)	810-900	Flight of summer generation 2 in Hungary with 4 yr. avg. flight duration of 52 days	(Sáringér and Deseo 1972)
Adult-Adult	10	390-410	10% ♂ emergence to 10% ♂ emergence	(Hrady et al. 1996)
	Not specified	387	Between flight peaks of 2 generations	(Deseo, 1971 reviewed in Hrady et al. 1996)
Male Flight	10	290-320	onset of flight summer generation; cumulative DD from Jan 1	(Hrady et al. 1996)
	10	530-760	50% male emergence summer generation; different locations; cumulative DD from Jan 1	(Hrady et al. 1996)
Complete life cycle”	10	420	Egg to first egg	(Charmillot et al. 1979)